Production Biology of Phytoplankton

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LONG-TERM GOALS

My long-term goal is to review creatively both our knowledge about the interaction of marine plankton with the hydrographic and chemical environment and the feedback from the planktonic processes to the abiotic environment. I use older observations and evaluations, as well as data collected by current programs. Understanding of the sea itself rather than the biology of marine organisms is being stressed.

OBJECTIVES

[1] To finish manuscripts on the geographic and seasonal distribution of satellite-estimated phytoplankton in the subarctic Pacific and the deep parts of the Bering Sea, the Arabian Sea, and the adjoining Laccadive Sea. [2] To pursue or initiate English translations of books in Russian, largely concerned with zooplankton distribution, identification, and production in warm seas. [3] To continue to co-operate with colleagues in India, mainly at the National Institute of Oceanography (India) in Goa (NIO). [4] To exhume and quality-check five years of Indo-Norwegian data from the Indian west coast shelf for a study of the near-bottom oxygen during the upwelling of the southwest monsoon.

APPROACH

The report concerns the second year of a three-year grant.

[1] The satellite-related work was principally based on individual scenes for the entire lifetime of the Coastal Zone Color Scanner (CZCS, late-1978 to mid-1986), which were rigorously reprocessed with a newly refined filter to avoid electronic overshoot that had not been used for NASA's Global Data Set. The reprocessing had largely been done by D.C. English under an expired NASA grant of mine, but for the Laccadive Sea by L.J. Lierheimer, a graduate student under my supervision, who was supported by funds other than from ONR (see under Results [1a-c]).

[2] I finance the book translations (also with minor SCOR and U.S. JGOFS support) elsewhere and do the editing. For the newly commissioned book, I had to revise all chapters twice. Editing of the new book (see under Work Completed [2d]) was facilitated by inviting the co-editor, Dr. S.A. Piontkovski, for one month from Stony Brook, NY, to Seattle with SCOR support.

[3,4] From January through mid-March 1998 I was in India, the travel costs borne by ONR/American Institute for Biological Sciences. Most of the time was spent instructing, learning, and consulting at NIO. I also visited institutes in Bangalore (Indian Academy of Sciences; Council for Scientific and Industrial Research) and Cochin (headquarters of the India-wide Central Marine Fisheries Research

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Institute, CMFRI). It was my second CMFRI visit (first one in 1995) to obtain release and bring into useable form a unique, but largely unused set of frequently repeated coastal (shelf and beyond) hydrographic sections of 1972 - 1975. Contrary to my expectations, a third visit will be required (January 1999, with the travel financed by SCOR in another context).

WORK COMPLETED

[1] With three manuscripts on satellite-estimated plankton chlorophyll completed (see next section), I finally have eliminated my backlog from previous studies under NASA grants.

[2] During the visit to Bangalore (see c.3., above), an agreement for printing the following five books was reached with Universities Press (India) in Hyderabad, a subsidiary of Orient Longman in Bangalore. The Indian Academy of Sciences obtained a subsidy from the Dept. of Ocean Development in Delhi. The price of the books is expected to be near $ 15 each so that they will be affordable to libraries or even individuals in the countries bordering the Indian Ocean. Rapid progress is now limited mostly my overcommitment, so that I cannot edit quickly enough.

[a] L.I. Sashina (deceased). 1985. Nauplii of Dominant Pelagic Copepods in the World Ocean. Naukova Dumka, Kiev. 237 pp. with 100 figures and 2 tables.

[b] L.I. Sashina (deceased). 1987. Reproduction, Growth, and Production of Marine Copepods. Naukova Dumka, Kiev. 155 pp. with 35 figures and 55 tables.

In the FY97 report I stated for the two Sashina books that I have the translations from the Russian in hand and am editing them. Since then I found the second translation to be so uneven and in part sloppy that I returned it for a better job.

[c] E.V. Pavlova. 1987. Motion and Metabolism of the Marine Plankton. Naukova Dumka, Kiev. 212 pp. with 55 figures and 41 tables.

During this year, the author has revised her earlier version and provided originals for all figures. The translation is almost completed, but needs to be edited by me and approved by the author.

[d] S.A. Piontkovski and K. Banse (eds.). In preparation. Synoptic Ecosystem Structure of the Upper Layers of the Open Northwestern Arabian Sea during the Northeast Monsoon of 1990.

This book, mentioned in the FY97 report, consists now of 16 chapters about a comprehensive Ukrainian expedition along closely-spaced grids, instead of our usual working along sections. The scope of the expedition extended from hydrography through nutrients, phytoplankton, heterotrophic bacteria, zooplankton including stages of copepods, myctophids (including stomach analyses), to squids. The second revisions and figures are in hand for 12 chapters. For two more, the first revisions have been returned to the authors for improvements.

[e] T.S. Petipa (ed., deceased) Mechanisms of Aggregation and of the Functioning of the Plankton Community in Ecosystems of the Indian Ocean. 17 chapters with numerous figures and tables and a small-format atlas with about 100 black-and-white maps.

The translation of this unpublished book manuscript (ready for printing in Russian in the Ukraine prior to the economic breakdown) for a similar expedition of 1980 in the same area and season as in [d], with some data for 1983 and 1985, has been launched with additional, partial U.S. JGOFS support.

RESULTS

[1] With the completed manuscripts abstracted below and the papers by Banse (1996) and Banse and English (1997), both supported by NASA, the seasonal and interannual distributions of near-surface phytoplankton have now been evaluated as chlorophyll for about 1/5 of the offshore ocean and put into context. The regions were chosen because they are in part High Nutrient-Low Chlorophyll areas (cf. the iron theory), in part because of JGOFS concerns. The work was preceded by a more broad-brush treatment of the world ocean by means of monthly averages of seasonal and interannual (1979-1986) CZCS data for 48 large (approximately 77,000 km^2) sites by Banse and English (1994).

[a] Banse, K., D.M. Bartolacci, D.C. English and M.E. Luther. Accepted. Seven years of Color Scanner-derived phytoplankton pigment for the Arabian Sea and correlations of 11 regional grand monthly means with wind pseudo stress, wind pseudo curl and total heat flux.

Abstract. The pigment observations of individual days by NASA's Coastal Zone Color Scanner (CZCS) between late 1978 and mid-1986 over the Arabian Sea north of 10°N, including the outer Gulf of Oman, are depicted as means, often only five days apart, for 13 subregions beyond the continental shelves. The data were reprocessed with a more restricted cloud screen than used for NASA's Global Data Set and exclude the bias from electronic overshoot. For 11 subregions south of 23°N, monthly pigment means are averaged for the entire period and correlated with climatological monthly means of wind pseudo stress, wind pseudo curl, and total heat flux in subregions essentially of the same shape.

The pattern derived from older in-situ observations, of one bloom during the southwest (summer) monsoon almost everywhere and one additional, late-winter bloom in the north is confirmed. The correlation analysis, handicapped by the incomplete or absent CZCS coverage during three months of the summer monsoon, suggests that pigment increases follow the months of physical forcing by a lag of one or possibly two months. The most conspicuous lack of correlation between the physical processes and pigment concentrations is the absence of enhancement of pigment in the central Arabian Sea during winter when a deep, cool mixed layer is regularly present. The biological reasons for genesis of blooms are briefly discussed. (For Deep-Sea Res. II; accepted after revision).

[b] Lierheimer, L.J. and K. Banse. Seasonal and interannual variability of phytoplankton pigment in the Laccadive (Lakshadweep) Sea as observed by the Coastal Zone Color Scanner.

Abstract. Based on Coastal Zone Color Scanner data of November 1978 through December 1981, the seasonal cycle of phytoplankton pigment in the upper part of the euphotic zone is established for the offshore Laccadive Sea, east of the islands on the Chagos-Laccadive Ridge to the Indian shelf break, north of 5°N and west of 79°E. Year-round, the pigment content is low, especially during the Transition Period prior to the Southwest Monsoon. The seasonal range is small, since there are no indigenous phytoplankton blooms; July-August, however, were poorly studied because of cloud cover. The abundant phytoplankton caused by the upwelling off India during the Southwest Monsoon remains essentially restricted to the shelf, but there are occasional large, zonal outbreaks into the open

Laccadive Sea, as well as others advected to the south of India. Interannually, differences during the Northeast Monsoon and the Transition Period are minor, but the differences in space and time of the outbreaks from the Indian shelf during the Southwest Monsoon were greatest during 1979 and smallest during 1981. The 1979 rainfall along the Indian west coast was unusually low while that of 1981 was average. In outbreaks and rain, 1980 was intermediate. (For Proc. Indian Acad. Sci. [Earth Planet. Sci.]; the figures are in hand, the text is being edited.)

[c] Banse, K. and D.C. English. Comparing phytoplankton seasonality in the eastern and western subarctic Pacific and the western Bering Sea.

Abstract. The observations of phytoplankton pigment by the former Coastal Zone Color Scanner were reprocessed for offshore areas of the eastern and the western subarctic Pacific with the western Bering Sea. The data comprise 1979 to mid-1986, with two or three years of good coverage especially early in the period. Means for the individual days for seven large offshore "boxes" in each of the two subdivisions are depicted and evaluated together with surface observations of chlorophyll a and nutrients by ships. Basically, the entire deep-water region is a High Nutrient (nitrate) - Low Chlorophyll (HNLC) regime, excepting the areas of discharge of subarctic water to the south, off Hokkaido and Washington - California. Eastern and western subarctic do not differ in respect to the seasonal pattern of phytoplankton. Spring and summer blooms are absent throughout. Apparently, the winter production of phytoplankton is high enough also in the west, in spite of a deeper mixed layer, to maintain enough zooplankton for suppressing these blooms. The mechanism leading to autumn blooms in some boxes, relatively close to the continents, is unclear. Lack of sufficient size fractionation data for phytoplankton is a serious impediment to understanding the seasonal phenomena. The seasonal pattern of pigment seems to be unaffected by interdecadal regime shifts. This holds probably also for the concentrations, so that satellite observations may tell little about such shifts. (For Prog. Oceanogr., special volume about the subarctic Pacific; the figures are in hand, the text is being revised.)

[3,4] Banse, K., S.W.A. Naqvi, M. Dileep Kumar, D.A. Jayakumar and J.R. Postel. (Submitted) Decadal changes of dissolved oxygen in the minimum of the Arabian Sea.

(First paragraph of ms. for Nature). Close to 1/2 of the total marine denitrification occurs in the water column, and about 1/3 of the latter takes place within the oxygen minimum of the Arabian Sea, the thickest of the three major oxygen-poor layers of the open sea. Besides formation of N_2, the O_2-deficiency enhances the production of the greenhouse gases N_2O and CH_4. Thus, the temporal variability of the intensity and geographic extent of this O_2 minimum are of global biogeochemical interest. For the first time, temporal trends over 35 years in oxygen and nitrite concentrations are studied in the upper 300 m of the minimum. Near 65°E, O_2 declined gradually, but significantly over possibly 5 deg. of latitude from 1962 into the early 1980's and has stayed low since then. Near 200 m depth, the area within the 0.2 ml/l O_2 isoline expanded by 1/4-1/3 to the south, and even more at 400 m depth, probably due to a change of meridional advection. On a decadal time scale, the oxygen minimum is not in a steady state. Moreover, repeated observations, including those at 2 drift stations, show marked variability with no clear seasonal trend superimposed on the long-term trends, which makes budgeting based on a few stations difficult. (The ms. was submitted to Nature but returned without review "because of insufficient urgency of the subject." The ms. needs to be re-formatted for Global Biogeochem. Cycles.)

IMPACT

I continue to utilize old data never studied before or not fully treated by the originators, in order to elucidate the regional oceanography of the Arabian Sea and other areas. The result, usually, is a new look at an old question, and/or an integration not previously achieved.

TRANSITIONS

For the FY98 work it is too early to tell. My previous publications are frequently cited, and I believe that my presence during meetings/workshops in the U.S. and visits to India help to integrate JGOFS studies in the Arabian Sea, and in India to focus new work on the shelf.

RELATED PROJECTS

Collaboration with colleagues at NIO and CMFRI continues, emphasizing the hydrography, including oxygen, and nitrogen metabolism on and off the shelf of the west coast of India. Only little progress has been made since the last report, owing to problems with original data and my other commitments.

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PUBLICATIONS

Banse, K. 1997. Irregular flow of Persian (Arabian) Gulf water to the Arabian Sea. J. Mar. Res. 55: 1049-1067 (ONR and NASA supported).